Hypothalamus and Posterior pituitary

INTENDED LEARNING OBJECTIVES (ILOs)

By the end of this lecture the student will be able to:

- ✓ List the anterior pituitary tropic and non-tropic hormones.
- ✓ Correlate the hypothalamic secretion to the anterior pituitary gland functions and secretions.
- ✓ Describe the feedback control of endocrine secretion.
- ✓ Describe the main effects of anterior pituitary hormones.
- ✓ Summarize the functions and regulation of Prolactin.

Hypothalamus and Pituitary gland

The **hypothalamus** is the region of the brain involved in coordinating the physiologic responses of different organs that maintain homeostasis. Hypothalamus is the main interface between the nervous system and the endocrine system. It is connected to pituitary gland by the pituitary stalk called infundibulum

Pituitary gland is a small gland situated at the base of the skull in the sellaturcica. It is considered a master gland; it orchestrates the functions of most of the body glands like thyroid gland, adrenal cortex, testes and ovary.

The pituitary has two anatomically and functionally distinct lobes, the ***posterior pituitary*** and the ***anterior pituitary***

The posterior pituitary is composed of nervous tissue ***(neurohypophysis)*** while the anterior pituitary consists of glandular tissue ***(adenohypophysis)***.

Hypothalamic-Hypophyseal Connections:

2 types of connections between the hypothalamus and pituitary:

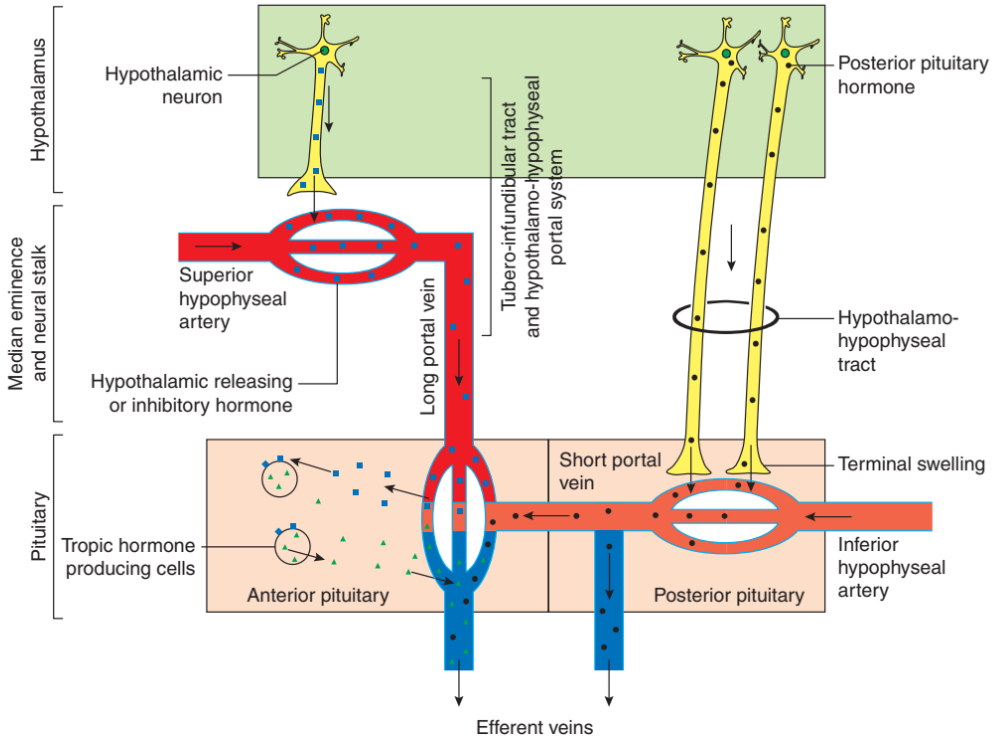
1. Between the hypothalamus and anterior pituitary gland in the form of a ***hypothalamic-hypophyseal portal circulation.***
2. Between hypothalamus and posterior pituitary gland in the form of ***hypothalamic-hypophyseal tract.***

The hypothalamus controls the pituitary gland by both neural and hormonal mechanisms

(1) Release of hypothalamic neuropeptides synthesized in hypothalamic neurons and transported through the **hypothalamo-hypophysial tract** to the **posterior pituitary gland**

(2) Neuroendocrine control of the anterior pituitary through the release of peptides that control **anterior pituitary gland** hormone release. There are six hypothalamic releasing and inhibiting hormones:

1. Corticotropin releasing hormone (CRH)
2. Thyrotropin releasing hormone (TRH)
3. Growth hormone releasing hormone (GRH)
4. Growth hormone inhibiting hormone (GIH): Generally called somatostatin;
5. Gonadotropin releasing hormone (GnRH)
6. Prolactin inhibiting hormone (PIH): Chemically dopamine.



Posterior pituitary gland (Neurohypophysis)

It releases 2 hormones ***Antidiuretic hormone*** and ***oxytocin***

Synthesis and secretion

The **ADH** neurons have their cell bodies primarily in the **supraoptic nuclei** of the hypothalamus. The **oxytocin** neurons have their cell bodies primarily in

paraventricular nuclei. Each nucleus also can produce the "other" hormone but in small amount.

Hormones then are transported down axons of these neurons to their endings in the posterior lobe to be stored in secretory vesicles. Secretion of hormones is initiated by action potential transmitted from the cell body in the hypothalamus, down the axon to the nerve terminal in the posterior pituitary. When the nerve terminal is depolarized by the action potential, Ca^{2+} enters the terminal, causing exocytosis of the secretory granules. The secreted hormones enter nearby fenestrated capillaries and are carried to the systemic circulation, which delivers the hormones to their target tissues.

N.B. **Oxytocin and vasopressin are typical neural hormones** *(Neurohormones are hormones released into the blood by neurosecretory neurons when an action potential reaches the axon terminals. The neurohormone is then distributed through the blood to distant target cells)*

Antidiuretic hormone (Vasopressin)

Action:

1. **Renal effect:**

ADH binds to its ***V2 receptor*** it increases cAMP which increases the permeability of the distal convoluted tubules and collecting ducts to water by promoting ***insertion of water channels*** (aquaporins specifically, AQP-2) in luminal membrane. Increasing water reabsorption through these ducts producing concentrated urine.

In the absence of vasopressin, the urine is hypotonic to plasma, urine volume is increased, and there is increase in net water loss.

2. **Contraction of vascular smooth muscle:**

The second action of ADH is to cause contraction of vascular smooth muscle (as implied by its other name, vasopressin). The receptor for ADH on vascular smooth muscle is a ***V1 receptor***, which increases IP3/Ca^{2+} leading to contraction of vascular smooth muscle, constriction of arterioles, and increased total peripheral resistance.

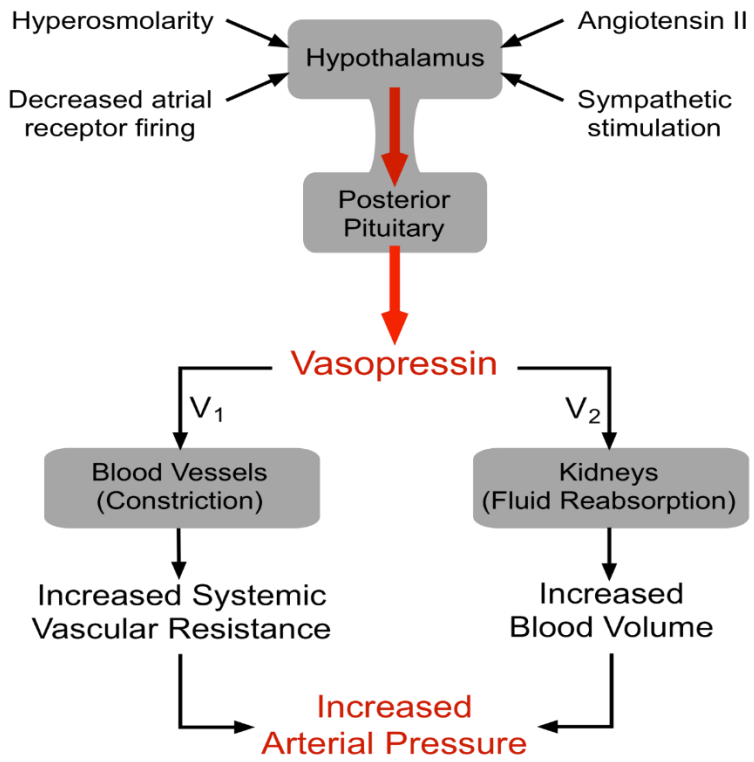
Regulation:

1- **Increased plasma osmolarity** is the most important physiologic stimulus for increasing ADH secretion. When a person is deprived of water, serum osmolarity increases. This increase is sensed by osmoreceptors in hypothalamus. Action potentials are initiated in cell bodies of the nearby ADH neurons and propagated down the axons,

causing the secretion of ADH from nerve terminals in the posterior pituitary.

The sensitivity of this system is quite high. As very small increase in plasma osmolality (as little as 1%) produces significant increases in ADH release

2- **Hypovolemia, or volume contraction** (e.g. hemorrhage), causes also stimulation of ADH secretion. Decreases in extracellular fluid (ECF) volume of *10% or more* cause a decrease in arterial blood pressure that is sensed by baroreceptors in the left atrium, carotid artery, and aortic arch. This information about blood pressure is transmitted via the vagus nerve to the hypothalamus, which directs an increase in ADH secretion. ADH then stimulates water reabsorption in the collecting ducts, attempting to restore ECF volume.
3- **Renin–angiotensin mechanism.** Hypovolemia also stimulates renin–angiotensin mechanism, which reinforces the release of ADH in response to hypovolemia and hypotension.
4- Pain, nausea, hypoglycemia, and various drugs (e.g., nicotine, opiates, antineoplastic agents) all stimulate the secretion of ADH. Ethanol, α-adrenergic agonists, and ANP inhibit secretion of ADH



https://hieker.com/antidiuretic-hormone-adh-market-2019-industry-outlook-comprehensive-insights-growth-and-forecast-2025/80483/

Abnormalities:

1- Diabetes insipidus (DI):
Patients with diabetes insipidus has defect in ADH secretion or renal response to ADH so their collecting ducts are impermeable to water, and the urine cannot be concentrated thus they produce large volumes of dilute urine, and they have and excessive thirst. The body fluids become concentrated (e.g., increased serum osmolarity, increased serum Na^+ concentration).
Types:

- ***Central (neurogenic)* diabetes insipidus** is caused by destruction of the hypothalamus and posterior pituitary by tumors, head trauma, infection and stroke. In this disorder, circulating levels of ADH are low, if fluids are withheld, these patients continue to produce an excessive urinary volume of dilute urine but if a synthetic ADH analogue is injection in these patients their urine osmolarity will increase.

- ***Nephrogenic* diabetes insipidus** the posterior pituitary is normal, but the principal cells of the collecting duct are unresponsive to ADH due to a defect in the V2 receptor, Gs protein, or adenylyl cyclase or it could be due to drugs e.g. lithium. In nephrogenic diabetes insipidus, ADH level is elevated due to stimulation of secretion by the increased serum osmolarity, and administration of exogenous ADH analogues does not decrease the urinary flow rate and urine osmolarity.

2- Syndrome of inappropriate ADH secretion (SIADH):
Excess ADH is secreted from an ectopic site (e.g. small cell carcinoma of the lung). High levels of ADH cause excess water reabsorption by the collecting ducts, which dilutes the body fluids (e.g., decreases plasma osmolarity and Na^+ concentration). The urine is inappropriately concentrated (i.e., too concentrated for the serum osmolarity).

Oxytocin

Action:

Oxytocin produces its actions by increasing intracellular Ca^{2+} levels

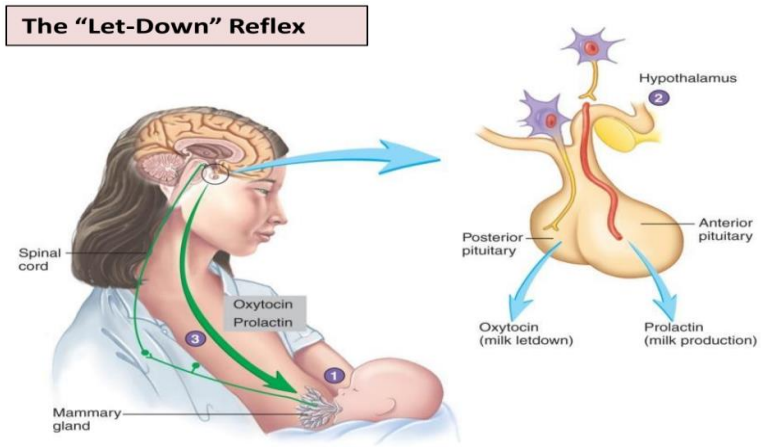
1. Milk ejection:

Oxytocin produces milk “letdown” or milk ejection from the lactating breast by stimulating contraction of myoepithelial cells lining the milk ducts.

Milk ejection is normally initiated by a neuroendocrine reflex (suckling reflex). When baby suckles, the sensory nerve endings or receptors located in skin of areola and nipple get stimulated. The sensory impulses are transmitted to the hypothalamus through somatic nerves leading to activation of hypothalamus which causes release of oxytocin from the posterior pituitary gland. The oxytocin is carried to the breasts through blood where it causes contraction of

myoepithelial cells that surround the outer wall of the alveoli producing milk ejection or milk let down.

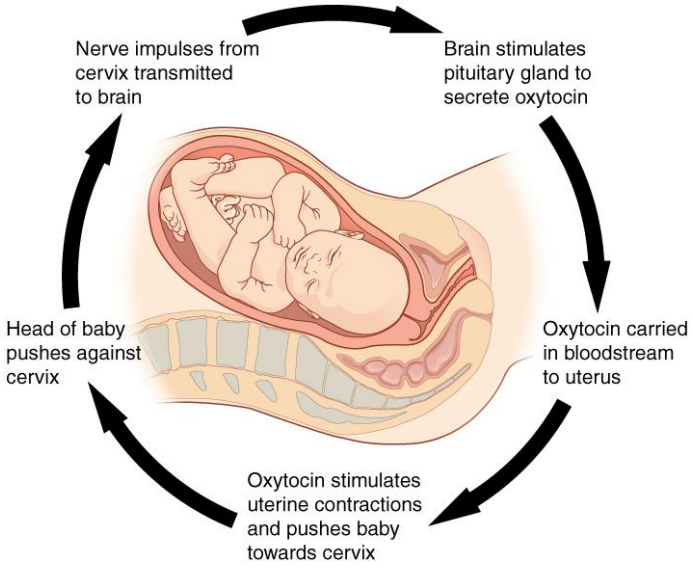
Milk ejection is also induced by sight, sound or crying of infant and thought of the infants ***(Conditioned response)***.



2. Contraction of the smooth muscle of the pregnant uterus.

During labor, stretching of the cervix by the fetus's head initiates impulses in the afferent nerves that are relayed to the hypothalamus causing secretion of sufficient oxytocin leading to contraction of the smooth muscle of the uterus, more stretch of cervix, more release of oxytocin, more uterine contraction ***(Positive feedback)***

The sensitivity of the uterine musculature to oxytocin is enhanced by estrogen and inhibited by progesterone. in late pregnancy, the uterus becomes very sensitive to oxytocin coincident with a marked increase in the number of oxytocin receptors



3. Oxytocin may also cause contraction of the nonpregnant uterus

These contractions facilitate sperm transport up the female genital tract to the uterine tubes, where fertilization normally takes place

4. Oxytocin has role in males

As Oxytocin level increases at the time of **ejaculation** which possibly causes increased contraction of the smooth muscle of the vas deferens, propelling sperm toward the urethra.

Regulation:

The secretion of oxytocin is increased by:

- Suckling stimulates oxytocin release (suckling reflex).
- Genital tract simulation during sexual intercourse in males and females.
- Dilatation of cervix during Labor through a positive feedback where release of the hormone causes an action which stimulates more of its own release.

SUGGESTED TEXTBOOKS

1. Ganong's Review of Medical Physiology, twenty-fifth edition 2016, McGraw-Hill Education, chapter 17-18, from page 307 to 334
2. Guyton and Hall textbook of medical physiology, thirteenth edition 2016, Elsevier, chapter 76, from page 939 to 950
3. Lauralee Sherwood Human Physiology: From Cells to Systems, Ninth edition 2016. CENGAGE, chapter 18, from page 646 to 652